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The Effects of Pacing on Academic Performance in Elementary School Students with Attention Difficulties

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To the Graduate Council:

I am submitting herewith a dissertation written by Emily Jane Fuller entitled "The Effects of Pacing on Academic Performance in Elementary School Students with Attention Difficulties." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in School Psychology.

Christopher H. Skinner, Major Professor

We have read this dissertation and recommend its acceptance:

Sherry K. Bain, Vey M. Nordquist, Amy L. Skinner

Accepted for the Council:
Dixie L. Thompson

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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THE EFFECTS OF PACING ON ACADEMIC PERFORMANCE IN ELEMENTARY SCHOOL STUDENTS WITH ATTENTION DIFFICULTIES

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Emily Jane Fuller
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Dedication

This dissertation is dedicated to my parents, Sharon and Eddie Fuller, whose incredible support, encouragement, and love helped me to achieve my goals.

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I wish to thank all those who helped me complete my Doctor of Philosophy degree in School Psychology. I would like to thank Dr. Christopher H. Skinner for his support and guidance during my tenure in graduate school. I would like to express my gratitude to Dr. Sherry K. Bain for her assistance and encouragement. Thanks to Dr. Vey Michael Nordquist and Dr. Amy L. Skinner for serving on my committee.

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Abstract

Researchers have investigated pacing and accuracy of students' academic work. However, studies investigating the effects pacing have mixed results regarding accuracy levels and student acceptability. Fuller, Krohn, Orsega, Skinner, and Williams (2009) conducted a pilot study examining the impact of slowing students down on their accuracy levels. Specifically, Fuller et al. (2009) had computers deliver multiplication problems one at a time. In the no-delay condition a new problem was delivered immediately after students provided an answer to the previous problem. In the delay condition, after students entered the answer to a problem there was a 7-second delay before the computer delivered the next problem. No significant differences in accuracy levels between the two conditions were found, suggesting that pacing had no effect on accuracy. However, response accuracy levels were very high, suggesting that a ceiling effect may have hindered researchers' ability to find significant differences.

The current study extended this research on pacing by using more difficult multiplication problems. In addition, researchers have suggested that attention required to complete tasks may be a moderator variable that influences the effects of pacing on accuracy levels. However, researchers have not examined attention as a between-subjects moderator variable. The two primary purposes of this study were to investigate whether decreasing the pace of academic work by artificially inflating intertrial intervals (delay between problems) influenced mathematics performance and to determine if students' attention levels moderated this impact. Participants were 111 fourth- and fifth-grade students who completed two sets of multiplication problems (7-second delay condition and no-delay condition). Students' teachers completed brief attention ratings for students that were used to separate students into high and low attention problems groups.

A mixed models ANOVA revealed no significant interaction which suggests that pacing does not interact with attention and accuracy. This study fails to support preceding studies claiming that a faster pace increases accuracy levels, but it did suggest that slowing the pace of students work does not hurt performance. Results indicate that previous researchers may be wrong about the influence of pacing on accuracy levels and attention as a moderating variable.

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Chapter 1

Introduction

Student Choice Behavior

While teachers can assign work to students and provide them with opportunities to learn and respond, it is the students ultimately who choose whether or not to engage in the assignment (Hawkins, Skinner, & Oliver, 2005; Skinner, Hall-Johnson, Skinner, Cates, Weber, & Johns, 1999; Skinner, Robinson, Johns, Logan, & Belfiore, 1996; Skinner, Wallace, & Neddenriep, 2002). Students may engage in behaviors that are disruptive to others, or they may simply engage in passive behaviors, such as avoiding the task by staring at their desk (Shapiro, 1996). Without the ability to use physical force to get students to actively engage in their assigned activities, it becomes important for educators to understand how to gain more control over their students' choices (McDowell, 1988).

According to Hernstein's (1961) matching law, when all else is held constant, students are more likely to choose behaviors that result in higher rates of reinforcement (Skinner et al., 1999). Likewise, Myerson and Hale (1984) posited that how students behave in the classroom (e.g., engaging in academic seatwork or engaging in disruptive behaviors) is a choice, and that educators can increase the probability that students choose to engage in academic activities by increasing the rate, quality, and immediacy of reinforcement for appropriate behaviors relative to competing inappropriate behaviors. Researchers who have conducted studies giving students a choice between two academic assignments have validated this theory. Results showed that students were more likely to choose the assignment that had the highest rate of reinforcement (e.g., Mace, McCurdy, & Quigley, 1990; Neef, Mace, & Shade, 1993; Neef, Mace, Shea, & Shade, 1992; Neef, Shade, & Miller, 1994). When rates of reinforcement for assigned tasks relative to rates of reinforcement for off-task behaviors were increased, students also engaged in assigned tasks more often (Horner, Day, Sprague, O'Brien, & Heathfield, 1991; Martens & Houk, 1989; Martens, Lochner, & Kelly, 1992; Skinner, Hurst, Teeple, & Meadows, 2002).

Student choice behavior is ultimately related to rate of responding, or pace, because the student must choose to engage in the task at hand in the first place. This behavior may result in a fast pace of responding. Alternately, students who choose to engage in off-task behaviors may display a slower pace of responding. Higher rates of reinforcement may be achieved by presenting an assignment at a faster pace (e.g., by a teacher or a computer), thereby increasing the chance that students choose to attend to the assigned task.

Discrete Task Hypothesis

The discrete task hypothesis holds that when working on an assignment with many discrete tasks (e.g., mathematics problems), the completion of each task serves as a conditioned reinforcer (Cates & Skinner, 2000; Cates, Skinner, Watkins, Rhymer, McNeill, & McCurdy, 1999; Logan & Skinner, 1998; McCurdy, Skinner, Grantham, Watson, & Hindman, 2001; Skinner, 2002; Skinner et al., 1999; Skinner, Fletcher, & Henington, 1996; Skinner, Robinson, et al., 1996; Skinner, Wallace, et al., 2002; Wildmon, Skinner, McCurdy, & Sims, 1999; Wildmon, Skinner, & McDade, 1998).

Skinner (2002) posited that this is caused by a positive or negative reinforcement history for completing academic assignments. For example, students may avoid looming aversive consequences for failure to complete an assignment (e.g., receiving a bad grade). Assignment completion also can be positively reinforced (Logan & Skinner, 1998), such as being able to engage in a more preferred behavior after completing an assignment (e.g. playing a game) (Skinner, 2002). This learned reinforcement history should lead to classical conditioning so that a completed assignment becomes a reinforced stimulus, and then anything preceding that could also become a reinforced stimulus through higher order conditioning (Pavlov, 1927). A completed assignment that is preceded by many discrete tasks (e.g., math drill worksheets) results in each completed discrete task (e.g., multiplication problem) becoming a reinforcing stimulus itself (Skinner, 2002; Skinner et al., 1999).

Hernstein's (1961) matching law indicates that increasing student response rates can lead to increased rates in learning. Many researchers have attempted to study the effects of speeding up or slowing down students' discrete task completion rates, most of which are focused on increasing these rates. These studies on manipulating discrete task completion rates have mixed results.

Explicit Timing

Explicit timing, a procedure in which students are told they are being timed while completing an academic assignment (Rhymer, Skinner, Jackson, McNeill, Smith, & Jackson, 2002), has been shown to improve students' academic performance during independent seatwork (Evans-Hampton, Skinner, Henington, Sims, & McDaniel, 2002;

Rhymer et al., 2002; Rhymer, Henington, Skinner, & Looby, 1999; Rhymer, Skinner, Henington, D'Reaux, & Sims, 1998; Van Houten, Hill, & Parsons, 1975; Van Houten, Morrison, Jarvis, & McDonald, 1974; Van Houten & Thompson, 1976). For example, Van Houten and Thompson (1976) implemented the explicit timing intervention during second-grade students' independent mathematics seatwork. They announced each 1-minute interval that passed and instructed students to circle the last problem they finished. They found that student rates of responding and accuracy levels increased under the explicit timing condition as opposed to a control situation when students completed the exercises but did not know they were being timed. Miller, Hall, and Heward (1995) found that students who were in special education classes also answered more problems correctly during 1-minute explicit timing intervals than during intervals without explicit timing, evidencing the procedure's effectiveness for these populations.

Rhymer et al. (1999) compared the explicit timing procedure to a control condition with no overt timing in African-American and Caucasian second-grade students completing addition and subtraction problems. They found no cross-group differences. Both African-American and Caucasian groups completed more problems per minute during the explicit timing condition (increased response rates), and accuracy remained consistent with no increase across either conditions.

The explicit timing procedure also has been examined for its impact on reading performance during individually administered curriculum-based measurement (CBM) assessments (Derr & Shapiro, 1989; Derr-Minneci & Shapiro, 1992). When students were aware they were being timed, their words correct per minute was higher than their words correct per minute when they were unaware of the timing procedure.

However, some researchers have found a decrease in accuracy levels under explicit timing conditions. Rhymer et al. (1998) examined explicit timing with third-grade students completing math sheets with simple addition, subtraction, and multiplication problems. They found that problem completion rates increased during the explicit timing condition, but accuracy levels decreased with explicit timing. After examining the data, the researchers divided students into three groups based on their pre-intervention accuracy levels (low, medium, or high). They then found that students who were categorized as having low or medium pre-intervention accuracy levels had more substantial decreases in accuracy during the explicit timing condition. Rhymer et al. concluded that the effectiveness of the explicit timing procedure was moderated by the students' existing skill levels.

Rhymer et al. (2002) suggested that the previous study (Rhymer et al., 1998) may have had different results had the researchers examined the type of mathematics problems that the students were completing, so to investigate this possibility, they compared the explicit timing intervention to a no timing condition with sixth-grade students completing mathematics problems. Students each completed assignment sheets consisting of 98 addition, subtraction, and multiplication problems. They each completed three sets of assignment sheets under the explicit timing condition and three sets of assignment sheets under the no timing condition. Results showed that students were faster and more accurate on the addition problems than the subtraction and multiplication problems, and they were faster and more accurate on the subtraction problems than the multiplication problems. This suggests that the effectiveness of the explicit timing intervention may be influenced by problem difficulty. Students also completed significantly more problems per minute in the explicit timing condition than in the no timing condition. However, no significant difference was found in percent of completed problems correct between the explicit timing and no timing conditions. These results mimic those of Rhymer et al. (1999), but contrast with studies done by previous researchers reporting lower accuracy levels with explicit timing (e.g., Rhymer et al., 1998) or higher accuracy levels with explicit timing (e.g., Van Houten and Thompson, 1976).

In sum, the explicit timing procedure increases student response rates. However, research is mixed about its effect on problem accuracy. Problem difficulty and existing skill levels may also be confounding factors. The link between increased response rates and resulting accuracy levels remains unclear.

Additive/Substitutive Interspersal

Another strategy to increase rate of reinforcement in academic assignments is known as the interspersal procedure (Hawkins et al., 2005). The interspersal procedure operates by either adding (additive interspersal procedure) or replacing (substitutive interspersal procedure) items in academic work. The new items are usually easier or take less time to complete (e.g., simple arithmetic problems added into a worksheet on long division) (Skinner, 2002). The interspersal procedure is therefore a technique used to increase discrete task completion rates.

Studies on the additive interspersal procedure focused on students' choice between a control assignment with a certain number of target items (e.g., 15 three-digit by two-digit multiplication problems) and an experimental assignment with the same number and type of target items, but with easier and/or briefer items interspersed in the assignment (e.g., 3-digit by 1-digit multiplication problems). Studies on the substitutive interspersal procedure modified the experimental assignment by replacing target items with easier and/or briefer items instead of adding more problems (Hawkins et al., 2005).

The interspersal procedure has been validated in studies showing that significantly more students chose to work on assignments where the substitutive interspersal procedure had been implemented (e.g., Billington, Skinner, & Cruchon, 2004; Billington, Skinner, Hutchins, & Malone, 2004). Additionally, studies also have demonstrated the effectiveness of the additive interspersal procedure, as significantly more students chose to work on the longer experimental assignments with briefer and/or easier items interspersed (e.g., Billington et al., 2004; Cates & Skinner, 2000; Meadows & Skinner, 2005; Skinner, Fletcher, et al.,1996; Teeple & Skinner, 2004; Wildmon et al.,1998; Wildmon et al., 1999; Wildmon, Skinner, Watson, & Garrett, 2004). Studies measuring continuous choice (i.e., on-task) behavior also have validated the interspersal procedure by measuring the amount of time students work on the control assignment or the experimental interspersal assignment. Results show that the additive and substitutive interspersal procedures increase students' on-task behavior and decrease maladaptive behaviors (e.g., Dickinson & Butts, 1989; Horner et al., 1991, McCurdy et al., 2001; Skinner, Hurst, et al., 2002).

Researchers also have examined accuracy and learning rates with respect to the interspersal procedure. While it is difficult to determine whether the substitutive interspersal procedure is responsible for an increase in accuracy levels because the number of target items is not held constant across conditions, the additive interspersal procedure can be evaluated for accuracy effects (Hawkins et al., 2005). Studies on the additive interspersal procedure have shown consistent accuracy levels across conditions (i.e., no increase or decrease in accuracy from the control to the experimental condition) (e.g., Billington, Skinner, & Cruchon, 2004; Cates & Skinner, 2000; Skinner, Fletcher, et al., 1996; Teeple & Skinner, 2004; Wildmon et al., 1998; Wildmon et al., 1999; Wildmon et al., 2004).

Conversely, results from two other studies examining the additive interspersal procedure have shown that it causes some increases in accuracy. Robinson and Skinner (2002) administered the Mental Computation and Multiplication subtests of the *KeyMath-Revised* (KM-R; Connolly, 1988) to seventh-grade students. Under the experimental condition, additional problems were added to both subtests after every second or third target item. Results showed a significant increase in accuracy under the interspersal condition for the Mental Computations subtest, but no significant difference in accuracy for the Multiplications subtests. Hawkins et al. (2005) conducted a similar study with fifth-grade students and found comparable results. One explanation for this phenomenon is that the added briefer and/or easier problems may have heightened students' attention (Neef, Iwata, & Page, 1977). The Multiplication subtests were written on paper and students could use paper to solve those problems, but the Mental Computations subtests were read aloud only once and students had to solve those problems mentally, without paper. Therefore, in order to respond accurately, students most likely had to demonstrate a higher level of sustained attention (Hawkins et al., 2005; Robinson & Skinner, 2002).

Interspersing the briefer items to the assignment may increase the pace at which students worked, resulting in greater attention and accuracy (Carnine, 1976; Van Houten & Little, 1982). Additionally, rate of reinforcement may be increased when briefer items are interspersed (Skinner, 2002), also enhancing attention and accuracy (Hawkins et al., 2005; Robinson & Skinner, 2002). The easier interspersed items may have increased students' confidence to do the assignment, further increasing attention and accuracy (Neef et al., 1977). Therefore, the additive interspersal procedure may be most effective in increasing accuracy on items that demand high levels of attention (e.g., items that require mental computation without the use of pencil and paper) (Hawkins et al., 2005).

The additive and substitutive interspersal procedures are based on the discrete task hypothesis and the idea of student choice behavior. Inserting problems (smaller tasks) that take less time to complete among longer problems results in an increased rate of reinforcement for the entire assignment. When rate of reinforcement is increased, that increases the probability that students will choose to attend to the task.

Rate-Building

Rate-building is characterized by fast, accurate, and repeated performance of learned skills (Doughty, Chase, & O'Shields, 2004; Porritt & Poling, 2008). Doughty et al. (2004) argue that while some studies have shown that rate-building increases the retention and endurance of skills (e.g., Binder, 1996; Johnson & Layng, 1996; Weiss, 2001), the benefit of a high rate of responding as opposed to a lower rate is confounded with rate of reinforcement and/or learning trials. Also, researchers such as Nevin (1992) claim that rate of reinforcement is linked to behavioral momentum (resistance to disruption) of responses to stimuli, which will be explained later in this chapter.

Porritt and Poling (2008) examined rate of responding by holding the number of learning trials and rate of reinforcement constant. They used pigeons performing a behavior chains task that required them to peck lighted red, white, or green keys in a box similar to an operant conditioning chamber. A trial consisted of the pigeon pecking a designated key, and after the correct key was pressed the house light turned off to indicate presentation of the next trial. After three trials (i.e., one chain) were completed, the pigeon would be granted access to grain. The experimenters were interested in three experimental conditions: no delays, within-chains delays (i.e., delays between trials before grain is given), and between-chains delays (i.e., delays between access to grain and beginning of next chain). Results indicated greater accuracy in the no delays condition than in the between-chains delays condition, and greater accuracy in the between-chains condition than in the within-chains condition.

Pacing

Fuller, Krohn, Orsega, Skinner, and Williams (2009) conducted a study on the effects of slowed pacing on student preference and academic accuracy of computerized mathematics problems completed by fourth- and fifth-grade students. Participants each completed two sets of multiplication problems on a computer. One set had a 7-second delay after the student submitted the answer to a problem before the next problem was presented, and the other set had no delay between problems. Results indicated that while there was no difference in accuracy between the two conditions, students preferred the no-delay condition to the delay condition, and they indicated that it took less effort to complete and was less difficult than the delay condition. The researchers warn that the finding of no accuracy differences may be due to a ceiling effect. The problems may not have been challenging enough for the students, resulting in correct answers for most of the problems.

Grobe and Pettibone (1975) examined the effect of instructional pace (slow, moderate, or fast) on student attentiveness. Instructional pace was the syllabication rate at which a lecture was presented to students, and student attentiveness was operationally defined and videotaped to gather data. The researchers found that a fast presentation rate increased individual student attentiveness more than a moderate presentation rate, and a moderate presentation rate increased individual student attentiveness more than a slow presentation rate.

The amount of time that students spend on a task is less important than the number of academic responses they make during that time (Heward, 1994; Skinner, Fletcher, et al., 1996). Therefore, faster-paced practice may be beneficial for students. Researchers have found that allowing subjects themselves to control their own pace has a significant effect on performance accuracy. For example, McFarling and Heimstra (1975) found that inspectors who engaged in self-pacing were more accurate than inspectors who were paced by machines. However, Scerbo, Greenwald, and Sawin (2001) suggested that these findings may have resulted because the self-paced inspectors could create longer inter-event intervals, giving them a chance to rest between inspections when they began to get tired, therefore increasing their ability to provide more attention to each inspection itself. Their hypothesis is based on the idea that the quality of sustained attention will diminish over time (Warm, 1984), known as the vigilance decrement (Davies & Parasuraman, 1982). Scerbo et al. (2001) examined the effects of self-pacing by having subjects participate in a vigilance task. They found similar results to McFarling and Heimstra (1975); subjects who can control the rate of task presentation performed better as they were less vulnerable to the effects of waning attention over time.

Behavioral Momentum

Researchers such as Nevin (1992) have suggested that behavioral momentum can be defined as response rate and resistance to change. According to this theory, when a pattern of ongoing responding is disrupted, response rate decreases, and the amount of decrease is contingent upon the nature and duration of the disruptor (Nevin & Grace, 2000). Fath, Fields, Malott, and Gossett (1983) designed an experiment using pacing to produce identical variable interval schedules and response rates. When food was presented to pigeons in varied durations independently of a response during periods between components in single test sessions, response rates decreased in proportion to the duration of the food presentation. When a response to a stimulus suddenly causes discomfort, the discomfort interrupts the behavioral momentum and acts as a barrier that results in a weakened likelihood that the response will occur again, thereby decreasing response rate (Nevin & Grace, 2000).

Other researchers have produced studies on behavioral momentum showing that using sequences of high-probability requests can result in increased task compliance and persistence (e.g., Belfiore, Lee, Scheeler, & Klein, 2002; Belfiore, Lee, Vargas, & Skinner; 1997; Mace & Belfiore, 1990). One variable of interest in these studies was the amount of time subjects took to initiate high-probability tasks after engaging in low-probability tasks, as well as the amount of time subjects took to initiate low-probability tasks after engaging in high-probability tasks. This can be measured by time between problems. The results help to explain the phenomenon of the interspersal procedure. When students engage in high-probability tasks (e.g., a math problem), a momentum-like effect is produced and students are more likely to begin another problem and begin it more quickly than if it were not preceded by a high-probability problem. The amount of time a student takes to begin a problem after finishing another is called response latency. This is of interest when considering the potential effects if one's behavioral momentum is interrupted by a delay between problems that is longer than the student's natural response latency between problems.

Attention

Attention and ADHD are common concerns of educators. As of 2006, approximately 4.5 million children in the United States ages 5 through 17 have been diagnosed with ADHD (Center for Disease Control [CDC], n.d.). Prevalence estimates of ADHD in school-aged children range from 3% to 7% (American Psychiatric Association [APA], 2000. Understanding how the conditions in which these students perform well (or poorly) can lead to more effective interventions.

Attention can be broken into two categories: sustained attention and selective attention. The amount of concentration allocated to a task tends to decrease over time with sustained attention (Shalev & Tsal, 2003). Selective attention can be described as the ability to focus on relevant information despite the presence of irrelevant information (Lerner, 1985). Both aspects of attention are important for educators to consider, as they can have serious implications when students are expected to consistently perform their best.

According to Sonuga-Barke (2002), individuals with ADHD display a preference for immediacy, aversion, or intolerance for delay. Researchers have studied this relationship between ADHD and delayed rewards (Kuntsi, Oosterlaan, & Stevenson, 2001; Kuntsi, Stevenson, Oosterlaan, & Sonuga-Barke, 2001; Schweitzer & Sulzer-Azaroff,1995; Tripp & Alsop, 2001) and have found that it exists independently from inhibitory deficits, which are often associated with ADHD (Sonuga-Barke, 1994; Sonuga-Barke, Williams, Hall, & Sexton, 1996). Researchers also have shown that children with ADHD are more likely to attend to a stimulus which produces immediate rewards and overall delay is reduced (Dalen, Sonuga-Barke, Hall, & Remington, 2004; Songua-Barke, Taylor, & Smith, 1992), and that they are less likely to attend to a stimulus when they have access to outside stimulation during delay intervals (Antrop, Stock, Verte, & Roeyers, 2004).

Bitsakou, Antrop, Wiersema, and Sonuga-Barke (2006) conducted a study on the relationship between delay frustration and ADHD with a sample of 49 undergraduate students (mean age = 23). Participants were given two screening questionnaires, the

Adult AD/HD Self-Report Scale (AARS; Barkley & Murphy, 1998) to assess ADHD, and the Hospital Anxiety and Depression Scale (HADS; Zigmond and Snaith, 1982) to assess anxiety. They then were given a Delay Frustration Task in which they were asked to complete simple math problems presented on a computer. The subjects were instructed to press a response button to select the right answer from a list of answer options. The majority of the time after pressing the response button, the next problem would immediately appear with no delay. However, after some of the problems there would be a post-response delay after pressing the response button but before the next question was presented. The researchers hypothesized that individuals with high ADHD symptoms would become more frustrated with the delay than those with low ADHD symptoms and respond by repeatedly pressing the response key in order to escape the delay and elicit the next question. The number and duration of response key presses during the delay intervals represented delay-related frustration in this study. Results indicated that individuals categorized as high ADHD and those categorized as low ADHD experienced more frustration with the delayed problems than with the non-delayed problems. However, individuals in the high ADHD category experienced significantly more frustration with the delayed problems than those in the low ADHD category, and that difference was even more exacerbated when controlled for anxiety.

Varying attention levels between students are applicable when considering response rates and pacing. Students with poor attention may tire easily of a task or have difficulty ignoring distracting stimuli. Enhancing response rates may increase the likelihood that students will choose to engage in a task and continue working due to higher rates of reinforcement. However, slowing a student's pace may cause an interruption in behavioral momentum and increase the likelihood that he/she will engage in off-task behaviors, especially if the student has attention difficulties. Accuracy level in students with attention difficulties is a variable that is yet to be explored in pacing literature, and it is particularly interesting in view of the mixed results that studies have shown between speed of pace and accuracy.

Summary and Purpose

It is important for educators to learn how to manage and predict student choice behavior so students spend more time engaged in academic work and less time engaged in off-task behaviors (McDowell, 1988). Research in education has largely focused on increasing students' discrete task completion rates (e.g., Hawkins, et al., 2005; Rhymer et al., 1999; Van Houten & Thompson, 1976), the results of which are mixed. Researchers who study behavioral momentum (e.g., Nevin, 1992; Nevin & Grace, 2000) suggest that delays might lessen the likelihood that students will continue to stay engaged in their academic work, and individuals with attention problems especially have an intolerance for delay (Bitsakou et al., 2006; Sonuga-Barke, 2002).

The purpose of this study is to examine the hypothesis that delays during inter-trial intervals interact with time to complete tasks, accuracy, and student preference while students are working high-attention computerized mathematics problems. Of particular interest is the prediction that students exhibiting high attention problems in the classroom will have significantly different results in accuracy, preference, and time (i.e., they will answer more problems incorrectly and work slower when computerized delays are incorporated, and they will prefer the no-delay condition over the delay condition) than students who display minimal attention difficulties. This study differs from other studies related to pacing because students' pace is decreased rather than increased, accuracy and attention are both measured, and students displaying attention difficulties are examined in comparison to those without attention problems.

Research Questions

The following questions will be addressed:

1) Do students with and without attention problems complete computerized math problems with different accuracy levels in the delay versus the no-delay condition?

2) Do students, regardless of attention levels, complete problems with higher accuracy levels on the delay or no-delay condition?

3) Do students, regardless of attention levels, take significantly longer time to answer problems in the delay condition than in the no-delay condition?

4) Do students, regardless of attention problems prefer the no-delay condition significantly more than the delay condition?

Chapter 2

Methods

Participants and Setting

Data were collected toward the end of the spring semester in 2009 from fourth- and fifth-grade elementary school students at two elementary schools in East Tennessee. Students from 16 classrooms participated in the study. The researcher wanted to use math problems that could be completed mentally but were complex enough to challenge the students' attention levels. Therefore, the sample was selected purposefully at grade level because fourth- and fifth-grade students can do multiplication mentally, but multiple-digit multiplication problems would strain their attention. Students who returned signed parental consent (Appendix A) and student assent (Appendix B) forms were provided laptop computers in the library under the researcher's supervision in order to complete the study.

Out of the 16 classrooms participating in the study, 123 students returned parental consent forms. Of those, 12 students (nine males and three females; eight fourth-grade and four fifth-grade students) did not complete the study because (a) 4 students were absent, (b) 3 students voluntarily quit before the necessary amount of data could be obtained from them, and (c) 5 students did not finish the study in the time allotted. Additional demographics could not be obtained from these participants. Therefore, a total of 111 subjects finished the study and were included in the data analysis.

Approximately 25% (28) of these students attended an urban multicultural school, while 75% (83) attended a larger rural school. Fourth-grade students comprised roughly

52% (58) of the sample and fifth-grade students made up about 48% (53) of the sample. Participants ranged in age from 8 to 12 years old, with a mean age of 10.23 (*SD* = 0.78). Approximately 45% (50) of the subjects were male and 55% (61) were female. Additionally, 1% (1 student) was African-American, 78% (87) were Caucasian, 10% (11) were Hispanic, 5% (6) were Native American, and 5% (6) described their ethnicity as "other." Possible confounding characteristics such as socioeconomic status and family background (e.g., parent education) were not examined. However, due to random assignment, they were not considered to affect the outcome of the study.

Each student's teacher completed the inattention questions on the ADHD Symptom Checklist-4 (ADHD-SC4; Gadow & Sprafkin, 1997) (Appendix C), described below. Each of the 9 items on the ADHD-SC4 Inattention Scale had a possible score range of 0 to 3. Totaled scores for the sample ranged from 0, indicating no attention problems, to 27 indicating extreme attention problems. The average attention score for the sample was 5.54 with a standard deviation of 6.38. However, because so many ADHD-SC4 scores were 0 or 1, the mode was 0 and the median was 3. In addition, teachers indicated that five participants were on medication for ADHD. One was taking Concertia, one was taking methylin, one was on an herbal patch, and two others were taking unknown medications for ADHD. ADHD-SC4 scores for these five students on medications were 8, 9, 13, 17, and 18. The lack of high attention problems scores for these participants suggests that the medications may have been effective. Regardless, these students were included in the sample as the teachers were instructed to fill out the form based on their most recent classroom behaviors (i.e., when they were on medication) and they were taking the medication when they participated in the study.

Students completed the study in a quiet room in the school with laptop computers arranged on tables by the researcher. In the urban multicultural school, this room was a teachers' lounge with a note on the door indicating that research was being conducted in the room. In the larger rural school, students were taken to the library when the librarian had no classes. Both rooms had round tables, and the researcher used five tables and arranged three to four laptops on each one. No more than 20 laptops were set up at once, depending on the number of students in each group. The laptops were plugged into power sources using extension cords. The researcher and another school psychology graduate student quietly walked around the room to monitor students and answer any questions. The rooms were kept reasonably quiet and unobtrusive. No computers malfunctioned during this study.

Materials

Computer program. Students participating in the study worked on a mathematics computer program developed by a computer science graduate student at a southeastern state university. Before collecting data, the researcher tested multiplication problems of varying difficulty with a random sample of six fourth- and fifth-grade students from one of the schools to determine which types of problems the students answered correctly 50 to 75% of the time. Using this information, the researcher then developed two sets of 15 problems each that were equivalent in difficulty to reduce the possibility of the computer randomly generating easier problems in one condition so that the conditions could be better controlled and compared. This combination of multiplication problems that were either 2 digits by one digit or 3 digits by one digit and included carrying were shown one at a time on the computer screen.

Students worked on one form of the program (experimental or delay, or control or no-delay) by answering 15 problems. They then answered a brief demographics survey (age, grade, gender, race), which was followed by the other form of the program (delay or no-delay) requiring them to work 15 more problems.

The no-delay form of the program provided immediate transitions from one problem to the next after the student entered an answer. The delay condition incorporated a computerized delay of 7 seconds after the student submitted the answer to a problem before the next problem appeared on the screen. This 7-second delay was chosen based on trial and error. Specifically, a researcher group consisting of 6 graduate students tested varying lengths of delay until they reach consensus that a 7-second delay was long enough to irritate each participant, but not overwhelm them so much that they would want to quit doing the problems.

The students were given another brief questionnaire following the completion of both conditions that asked them to rate on a Likert scale of 1 to 5 how difficult they thought each condition was and how much effort they put into each condition. Finally, students were told that they had to complete one more computer assignment, but they could choose the assignment type (first or second assignment). After submitting the questionnaire, they worked on another set of problems similar to the condition they chose (delay or no delay between problems), but the problems were much easier and did not involve carrying. This third set of problems consisted of an infinite number of problems so all students would continue to work until everyone was finished with at least the first two sets of problems and the last questionnaire. Data from this set were not analyzed; it was given merely to collect data on student choice and to keep students busy and quiet as peers worked on experimental or control assignments.

Attention scale. For each student returning a signed parental consent form, that student's homeroom teacher indicated whether or not the student was on medication for ADHD (and if so, what medication) and completed items one through nine in Category A of the ADHD Symptom Checklist-4 (ADHD-SC4; Gadow & Sprafkin, 1997). The ADHD-SC4 is a 50-item rating scale developed by the authors to gauge several areas of maladaptive behavior according to criteria outlined in the *DSM-IV-TR* (APA, 2000) for children ages 3 through 18 years old. It also is sensitive to side effects children may be experiencing due to stimulant medication. The ADHD-SC4 is mainly used as a screening instrument to assess Attention-Deficit/Hyperactivity Disorder (ADHD) and Oppositional Defiant Disorder (ODD), but also includes a Peer Conflict Scale and a Stimulant Side Effect Checklist, making it suitable for evaluating the effectiveness of interventions for disruptive behavior (Angello, Volpe, DiPerna, Gureasko-Moore, Gureasko-Moore, Nebrig, & Ota, 2003). It includes a form that can be completed by a parent and/or teacher in approximately 5 minutes. The first nine items in Category A are designed to assess inattention, while rest of the items in Category A (10 through 18) examine hyperactivity. Therefore, for purposes of this study, only items one through nine in Category A were completed by the students' homeroom teachers and examined by the researcher.

The authors of the ADHD-SC4 have provided updated normative data (Gadow & Sprafkin, 1999). The data are based on a sample of 1,844 parents and 2,715 teachers who completed the instrument for children and adolescents 3 to 18 years old. Normative data were collected across several geographic regions and are reported by age (3-5, 6-12, 13-18) and sex.

The ADHD-SC4 has good psychometric properties (Angello et al., 2003). The authors report a test-retest reliability coefficient of .70 for the teacher-completed checklist, and internal consistency coefficients ranging from .92 to .95. Correlations between the teacher-completed ADHD-SC4 and relevant subscales of other rating scales used to assess ADHD, specifically the Teacher Report Form (Achenbach, 1991) and the IOWA Conners' Teacher's Rating Scale (Loney & Milich, 1982) ranged from .45 to .88. Data concerning predictive validity for a sample of preschool- and elementary school-aged children yielded significantly different scores on the teacher-completed ADHD-Inattentive Type category between outpatient clinic and normal school samples across age groups (Gadow & Sprafkin, 1997). Diagnostic sensitivity (i.e., the measure's ability to identify students who have previously been identified as having ADHD) for the ADHD-SC4 teacher report ranged from alpha coefficients of .61 to .89, and specificity ranged from .57 to .94.

Procedures

The fourth- and fifth-grade classroom teachers agreeing to participate in the study were given parental consent forms (see Appendix A) to pass out to students during class time. For those students who returned the consent form with a parent/legal guardian's signature, their homeroom teacher completed items one through nine on the ADHD-SC4 and returned the form to the researcher.

The researchers assigned students to groups using randomized stratified (across grade level and attention scores) assignment procedures. The researcher then placed the participants in groups of no more than 20 students, which resulted in four groups of fourth-grade and four groups of fifth-grade students. Because the teachers wanted to keep classrooms of students who were participating in the study together, the researcher gave each student an identification number that correlated with a computer. The researcher pre-assigned students to computers by putting one to two classrooms in each grade together and counterbalancing their attention scores from each class so half of the students with low attention problems and half of the students with high attention problems would receive one condition of the experiment first and the others would receive the other condition first.

On the day of data collection, the researcher and another school psychology graduate student took one group at a time to a quiet room with laptop computers set up and passed out student assent forms (see Appendix B). The other school psychology student observed and recorded the researcher's behavior using a procedural integrity checklist (see Appendix D). Procedural integrity was 100%, which suggests that all groups received approximately the same experience. The researcher read the student assent form aloud with the students and asked for any questions. The students were then told to sign and date the forms if they agreed to participate. They were informed that any students who did not agree to participate or who voluntarily decided to stop the study early would be escorted back to their classroom to stay with their teacher. Only those students who reviewed and signed the assent form participated in the study.

The researcher then read directions aloud for the students, including how to use the laptop computers, and asked for any questions before they were told to start. Each group was allotted 30 minutes to complete the study on the computer. All students were stopped at the same time; those students who were not finished within 30 minutes were stopped with the rest of the group and their data were thrown out due to incompletion. After the students were stopped, the researcher debriefed the group by explaining the purpose of the experiment to them.

The computer program stored data on external storage devices, including the order in which the conditions were presented to each student, the demographic and survey information, time taken to complete each problem, time taken to complete each phase, and problem accuracy. Only data from the first two phases were analyzed. The researcher linked students' attention scores to their computer data in a database using their assigned identification codes.

Design and Analysis

Effects of pacing and attention on math accuracy. The primary dependent variable was the number of multiplication problems the subjects answered correctly in each condition. Response accuracy was calculated for each student by dividing the number of problems correct by 15 (the total number of problems in each condition) and multiplying by 100. A two-by-two mixed model ANOVA was used to analyze response accuracy data. The within-subjects factor was condition (delay or experimental condition and no-delay or control condition) and the between-subjects factor was attention level (high and low). Random stratified assignment (across grades and attention levels) was used to counterbalance the sequence of the within-subjects factor.

Two exploratory analyses were run to test for differences between pacing, accuracy, and attention. A within-subjects t-test was run to determine any differences in accuracy scores between the delay and no-delay condition. Additionally, a Pearson's 2-tailed test was conducted to test for a relationship between attention scores and accuracy scores.

Problem completion time. Completion times were reported for both sets of problems. For the delay condition, two different completion times were recorded. One included the 7-second delay between problems, and the other was adjusted for the 7-second delay. These times were analyzed via paired samples t-tests to investigate if students spent significantly more time on the delay condition.

Effort, difficulty, and choice. A factor analysis was run on items from the preference questionnaire (effort, difficulty, and choice) to determine if each item contributed to the construct of preference. The relationship between those items and students' accuracy and attention was then examined with paired samples t-tests (effort and difficulty) and a chi-square analysis (choice). In addition, a multivariate analysis was conducted to determine if students' choice of assignment could be predicted by how they ranked each condition on effort and difficulty.

Chapter 3

Results

There were two primary purposes of this study. The first was to investigate whether slowing down the pace of work by artificially inflating intertrial intervals (delay between problems) influenced mathematics performance. The second objective was to determine if students' attention levels moderated this impact. To address these goals, various planned statistical analyses designed to answer several discrete questions were applied. Additionally, several unplanned exploratory analyses were run. In this chapter, summary descriptive statistics are presented followed by results of our analyses.

Descriptive Statistics

Prior to collecting these data there was no way to determine how many students would fall into the low, moderate, and high attention problems categories based on their scores on the ADHD-SC4 measure. The score range for low, moderate, and high attention problems is 0-14, 15-21, and 22-27 respectively (based on 9 items each with a possible score range of 0 to 3 points). Table 1 provides a frequency distribution for the 111 participants. This table shows that 100 students fell into the low attention problems category, 7 fell into the moderate attention problems category, and 4 students were categorized as having high attention problems. Thus, our pool of students falling into the moderate and high attention problem groups was insufficient to run an ANOVA based on these categories. Therefore, when running the mixed models ANOVA, the between subjects factor was based on groups formed from the approximate top third and bottom third scores on the ADHD-SC4 rating scale.

Table 1 shows that 39 students scored 0 or 1. This group was the lowest attention problems group. The highest attention problems group was comprised of the 38 students who scored 7 or above on the ADHD-SC4 measure. This left 34 students who fell into the middle group. Table 2 provides the summary demographic statistics for each attention problems group (low, moderate, and high). Table 3 shows the spread of demographics across the attention problems groups.

Effects of Pacing and Attention on Math Accuracy

A two-by-two mixed model ANOVA was used to evaluate the interaction between pacing and attention on math accuracy. The within-subject variable was pacing, which had two levels, delay and no delay. The across subjects variable was attention. For this variable we only analyzed the low attention problems and high attention problems groups. The moderate attention problems group was excluded because their scores were too similar to students in the other two groups.

Table 4 provides the means and standard deviations for groups by conditions. Figure 1 depicts this data. The ANOVA, using Wilks' Lamda, revealed no significant interaction between attention and pacing on accuracy $F(1,75) = 0.066$, $p = .798$. The lowest attention problems group's mean accuracy was 9.42 ($SD = 4.79$) and the highest attention problems group's mean accuracy was 6.75 ($SD = 5.24$). Analysis of the main effect for the between-subjects variable (attention groups) was significant, $F(1) = 5.71$, $p = .019$. For the no-delay condition, mean accuracy was 7.90 ($SD = 5.05$) and the mean for the delay condition was 8.31 ($SD = 5.35$). Analysis of the main effect for the within-subjects variable (pacing) was not significant, $F(1) = 2.147$, $p = .147$.

Table 1

Frequency Distribution for Sample

Attention score	Frequency	Percent	Cumulative percent
0	26	23.4	23.4
1	13	11.7	35.1
2	16	14.4	49.5
3	4	3.6	53.2
4	6	5.4	58.6
5	6	5.4	64.0
6	2	1.8	65.8
7	2	1.8	67.6
8	4	3.6	71.2
9	8	7.2	78.4
10	4	3.6	82.0
11	3	2.7	84.7
12	2	1.8	86.5
13	3	2.7	89.2
14	1	0.9	90.1
16	1	0.9	91.0
17	4	3.6	94.6
18	1	0.9	95.5
21	1	0.9	96.4
22	1	0.9	97.3
25	1	0.9	98.2
27	2	1.8	100.0
Total	111	100.0	

Table 2

Demographic Characteristics of Attention Problems Groups (Low, Moderate, and High)

	Low		Moderate		High		Total	
Category	N	Percent	N	Percent	N	Percent	N	Percent
Gender								
Male	14	35.9	16	47.1	20	52.6	50	45.0
Female	25	64.1	18	52.9	18	47.4	61	55.0
Age								
8	0	0.0	0	0.0	1	2.6	1	9.0
9	2	5.1	8	23.5	6	15.8	16	14.4
10	19	48.7	15	44.1	18	47.4	52	46.8
11	18	46.2	11	32.4	11	28.9	40	36.0
12	0	0.0	0	0.0	2	5.3	2	1.8
Grade								
Fourth	15	38.5	19	55.9	24	63.2	58	52.2
Fifth	24	61.5	15	44.1	14	36.8	53	47.8
Race								
African-American	1	2.6	0	0.0	2	5.3	3	2.7
Asian	0	0.0	0	0.0	0	0.0	0	0.0
Caucasian	26	66.7	29	85.3	32	84.2	87	78.4
Hispanic	8	20.5	3	8.8	0	0.0	11	9.9
Native American	3	7.7	1	2.9	0	0.0	4	3.6
Other	1	2.6	1	2.9	4	10.5	6	5.4

Table 3

Demographic Spread across Attention Problems Groups (Low, Moderate, and High)

	Low		Moderate		High		Total	
Category	n	Percent	N	Percent	N	Percent	N	Percent
Gender								
Male	14	28.0	16	32.0	20	40.0	50	45.0
Female	25	41.0	18	29.5	18	29.5	61	55.0
Age								
8	0	0.0	0	0.0	1	100.0	1	9.0
9	2	12.5	8	50.0	6	37.5	16	14.4
10	19	36.5	15	28.8	18	34.6	52	46.8
11	18	45.0	11	27.5	11	27.5	40	36.0
12	0	0.0	0	0.0	2	100.0	2	1.8
Grade								
Fourth	15	25.9	19	32.8	24	41.3	58	52.2
Fifth	24	45.3	15	28.3	14	26.4	53	47.8
Race								
African-American	1	33.3	0	0.0	2	66.7	3	2.7
Asian	0	0.0	0	0.0	0	0.0	0	0.0
Caucasian	26	30.0	29	33.3	32	36.8	87	78.4
Hispanic	8	72.7	3	27.2	0	0.0	11	9.9
Native American	3	75.0	1	25.0	0	0.0	4	3.6
Other	1	16.7	1	16.7	4	66.7	6	5.4

Table 4

Summary Statistics for Attention Problems Groups across Conditions

Attention group	*n*	*M*	*SD*
		No-delay	
Low	39	9.18	4.80
Moderate	34	7.71	4.99
High	38	6.58	5.03
		Delay	
Low	39	9.67	4.82
Moderate	34	8.03	4.90
High	38	6.92	5.57

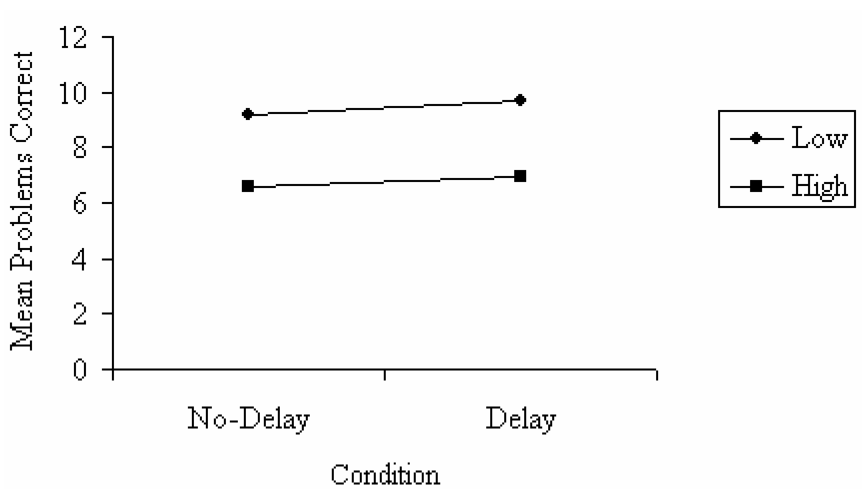

Figure 1: Interaction of mean problems correct for groups by conditions

These data indicates that the group with low scores on the ADHD-SC4 was much more accurate than the group with the highest scores on the attention problems scale, suggesting that attention scale scores are related to students' accuracy. However, the failure to find a main effect for pacing suggests that slowing students down with artificial intertrial intervals did not hinder performance. In fact, student performance was more accurate (though not significantly so) in the delay condition.

Exploratory analyses. Based on these results, two exploratory analyses were run. First, because the ANOVA required the elimination of the middle group, a within-subjects t-test was run across all participants to test for significant differences in accuracy across conditions. The mean number of problems correct in the no-delay (control) condition was 7.84 ($SD = 5.01$), and the mean number of problems correct in the delay (experimental) condition was 8.23 ($SD = 5.20$). This difference was not statistically significant, $t(110) = 1.70$, $p = .09$.

The ANOVA suggests that attention scores did moderate accuracy. Therefore, a second exploratory analysis was run to examine this relationship across all subjects. Using all participant scores, Pearson's 2-tailed test revealed a significant ($p < .01$ level) correlation between attention and accuracy scores for both the delay ($r = -.368$) and the no-delay ($r = -\ 0.357$) conditions. These results support the significant main effect found for groups in the ANOVA and show that the attention scores strongly correlated with accuracy across both conditions.

Summary of accuracy analysis. These analyses of the effects of pacing and attention on accuracy suggest that pacing had no significant impact on accuracy.

However, attention scores were related to accuracy across both the delay and no-delay conditions.

Problem Completion Time

Table 5 summarizes the descriptive statistics for total time across conditions. Note that for the no-delay condition, the dependent variable was seconds required to complete the 15 problems. In the delay condition, 14 intertrial intervals lasting exactly 7 seconds each were inserted between the 15 problems. Therefore, time spent working on problems in the delay condition was calculated two ways: the total number of seconds spent working and the total number of seconds spent working minus the intertrial intervals (i.e., total seconds minus 98). The 98 seconds were subtracted because we inserted 14 intertrial intervals, each exactly 7 seconds (14 x 7 = 98).

To investigate whether the artificial delay would influence problem completion rates, two dependent t-tests were run across participants to test for significant differences

Table 5

Descriptive Statistics for Total Time across Conditions

Condition	*N*	*M*	*SD*	*SEM*
No-delay	111	501.84	198.47	18.84
Delay [a]	111	461.74	170.69	16.20

[a]Numbers for the delay condition in this table were corrected for the 7-second delay (total number of seconds students spent working minus 14 [7-second] intertrial intervals)

in the average number of seconds to complete a 15-problem set. The first dependent t-test was conducted for total number of seconds required to complete all 15 problems across all participants. This included the 7-second delay after each problem in the delay condition. Mean seconds to complete all 15 problems was 501.84 (*SD* = 198.47) in the no-delay condition and 559.74 (*SD* = 170.69) in the delay condition. A dependent t-test revealed that these differences were significant $t(110) = 3.66$, $p < .01$. These results show that inserting the delays did reduce problem completion rates.

The second dependent t-test was conducted for total number of seconds required to complete all 15 problems across participants and excluded the 7-second delay in the delay condition. In this case, mean seconds to complete all 15 problems was 501.84 (*SD* = 198.47) in the no-delay condition and 461.74 (*SD* = 170.69) in the delay condition. A dependent t-test revealed that these differences were significant, $t(110) = 2.54$, $p < .01$. These results suggest that students in the no-delay condition spent significantly more time with the problems. However, it is not possible to determine exactly where this time was spent. Thus, they may have inserted their own intertrial intervals (e.g., by pausing) before working on problems, or they may have spent more time working on each problem.

Effort, Difficulty, and Choice

In addition to assessing students' performance, another purpose of the current study was to determine if pacing influenced student preference by analyzing effort and difficulty ratings and choice data. Before testing for significant differences across these measures, a factor analysis was run to determine if the effort and difficulty ratings and choice data all measured preference as a unifying construct. A principal component analysis with varimax rotation (Kaiser normalizing correction) revealed a three-factor model (see tables 6 and 7). This three-factor model suggests that three separate constructs are being measured (effort, difficulty, and choice) instead of contributing to the same broader construct of preference. Therefore, effort, difficulty, and choice responses were analyzed separately.

Effort and difficulty. The effort and difficulty items required Likert scale responding (rankings of 1 through 5). Summary statistics for these responses are provided in Table 8. Paired samples t-tests were run to test for significant difference across conditions. The mean difficulty rating for the no-delay condition was 2.57 (SD = .95). For the delay condition, the mean difficulty rating was 2.67 (SD = 1.02). These differences were not significant $t(110) = 0.95$, $p = .34$. For effort, the mean rating for the no-delay condition was 3.92 (SD = 1.18). For the delay condition, the mean effort rating was 4.05 (SD = 1.13). These differences were not statistically significant $t(110) = 1.85$, $p = .07$.

These data indicate that there was no significant difference in students' reports of difficulty or effort between the delay condition and the no-delay condition. However, mean effort rankings for both conditions were higher than mean difficulty rankings for both conditions. This suggests that while students viewed the multiplication problems as being of average difficulty, they believed that they put forth a high amount of effort into answering the problems.

Table 6

Factor Analysis (Rotated Component Matrix[a]) for Effort, Difficulty, and Choice

	Component		
Variable	1	2	3
Difficulty			
No-Delay	-0.02	0.89	0.18
Delay	0.11	0.75	-0.41
Effort			
No-Delay	0.94	0.05	0
Delay	0.95	0.03	-0.01
Choice	0.01	-0.02	0.96

Note. Extraction method: Principal component analysis;
Rotation method: Varimax with Kaiser normalization.
[a] Rotation converged in 4 iterations.

Table 7

Factor Analysis Component Transformation Matrix

	Component		
Component	1	2	3
1	0.94	0.32	-0.13
2	-0.34	0.83	-0.44
3	-0.03	0.46	0.89

Note. Extraction method: Principal component analysis; Rotation method: Varimax with Kaiser normalization.

Table 8

Summary Statistics for Difficulty and Effort Likert Scale Rankings

Condition	*M*	*N*	*SD*	*SED*
		Difficulty		
No-Delay	2.57	111	0.95	0.09
Delay	2.67	111	1.02	0.1
		Effort		
No-Delay	3.92	111	1.18	0.11
Delay	4.05	111	1.13	0.11

Choice. The choice item required the student to choose a third assignment. Therefore, this item produced nominal data that was analyzed using chi-square. Of the 111 students, 52 chose the no-delay condition and 59 chose the delay condition. Chi-square revealed that this difference was not significant, $\chi^2(1) = .44$, $p = .51$).

Exploratory analysis of preference. A multivariate analysis was conducted to determine if any of the four preference rating items (effort and difficulty questions about each condition) predicted students' assignment choice. Results revealed a significant difference, $F(5) = 469.45$, $p < .00$ (see table 9). Posthoc tests of between-subjects effects revealed that only the delay difficulty item was significant, $F(1) = 7.56$, $p = .01$ (see table 10). Specifically, these results showed that students who chose the no-delay assignment had significantly higher difficulty rankings for the delay condition than those who chose the delay assignment.

Therefore, a student who ranked the delay condition as being more difficult than the no-delay condition could be predicted to choose the no-delay condition to work again.

Table 9

Multivariate Analysis of Choice Prediction between Conditions

Effect Intercept	Value	*F*	Hypothesis *df*	Error *df*	Significance
Pillai's Trace	0.96	469.45	5	105	0
Wilks' Lambda	0.04	469.45	5	105	0
Hotelling's Trace	22.36	469.45	5	105	0
Roy's Largest Root	22.36	469.45	5	105	0

No other factors appeared to be able to predict assignment choice. For example, even students who ranked the no-delay condition as being more difficult than the delay condition could not be predicted to choose one condition over the other one to work again.

Summary of effort, difficulty, and choice analysis. These analyses of pacing on effort and difficulty rankings and student choice behavior suggest that pacing had no significant impact on students' perceptions of the assignment or the preference for which assignment they would rather work. However, assignment choice was somewhat predictable as students who ranked difficulty higher on the delay condition than the no-delay condition were more likely to choose the no-delay condition assignment.

Table 10

Posthoc Tests for Between-Subjects Effects of No-Delay Choice

Condition	Type III sum of squares	*df*	Mean square	*F*	Significance
			Difficulty		
No-Delay	0.08	1	0.08	0.09	0.76
Delay	7.43	1	7.43	7.56	0.01
			Effort		
No-Delay	0.05	1	0.05	0.04	0.85
Delay	0.02	1	0.02	0.02	0.89
Diff	1.37	1	1.37	0.23	0.63

Chapter 4

Discussion

Because no significant differences in accuracy were found between the no-delay condition and the delay condition, results indicate that slowing students' pace down does not affect accuracy scores. These results are similar to those found by Fuller et al. (2009), who posited that the lack of differences between the two conditions was due to a ceiling effect of accuracy scores. While that study found an average accuracy level higher than 93% in both conditions, the current study used harder multiplication problems and only found average accuracy levels of 52% and 55% in the no-delay and delay conditions, respectively. A ceiling effect was therefore avoided but differences between the two groups were still not significant, supporting the claim that slowed pacing does not influence students' performance.

These findings are similar to those found by other researchers who manipulated pacing. The additive interspersal procedure, which increased pace, resulted in consistent accuracy levels across conditions in some studies (e.g., Skinner et al., 2006; Wildmon et al., 2004). Furthermore, several studies have shown that the explicit timing procedure increased response rates without affecting accuracy levels (e.g., Rhymer et al., 1999; Rhymer et al, 2002). Rhymer et al. (2002) suggested that problem difficulty might influence pace and accuracy. The current study required fourth- and fifth-grade students to solve difficult (accuracy levels ranged from 44- 64%) multiplication problems. However, the current study where difficult problems were used, and the previous study where easier problems were used (Fuller et al., 2006) both revealed that slowing students' pace of work did not impact accuracy. Therefore, the current results failed to support previous researchers who suggest incorporating more rapid pacing on more difficult items to increase accuracy.

Researchers also proposed that there may be an interaction of pacing and attention required to complete tasks. Specifically, researchers found that the additive interpsersal procedure (a procedure that increases pace of responding) enhanced response accuracy on problems that required high levels of sustained attention, but not on similar problems that required low levels of sustained attention (Hawkins et al., 2005; Robinson & Skinner, 2002). The current study revealed no main effect for conditions. Thus, students did not perform more accurately on these high-attention tasks when pace was artificially slowed. In the current study, we also attempted to investigate attention across students. Our results analyzing accuracy across pacing conditions in low and high attention groups revealed no interaction effects. Consequently, our results failed to support this previous research that suggested that pacing may interact with attention to influence accuracy.

According to McFarling and Heimstra (1975), controlling one's own pace increases accuracy. In the current study, students in the no-delay condition had more control over pacing because there was no forced pause between problems. Consequently, the current results fail to support McFarling and Heimstra's hypothesis regarding control and accuracy.

Scerbo, Greenwald, and Sawin (2001) hypothesized that self-pacing allows subjects to insert their own pauses between trials, leaving them less susceptible to sustained attention waning over time. The current study manipulated pacing not by increasing response rate, but by decreasing it by forcing them to pause for at least 7 seconds between problems. Students took longer to answer problems during the no-delay condition than they did during the delay condition after the 7-second pause was removed for data analysis purposes. However, they took less time to answer problems during the no-delay condition than they did during the delay condition when the 7-second pause during the delay condition was included. This indicates that the subjects may have been inserting their own pauses in the no-delay condition, resulting in the conditions being more similar than researchers intended. However, there were still significant differences in total problem completion rates, making this limitation less serious.

Students in this study did not rank the delay condition and the no-delay condition differently on measures of effort and difficulty. Additionally, they did not choose to work one condition significantly more than the other. The lack of difference in difficulty and effort rankings is not entirely surprising as both sets of problems were designed to be equally difficult; the only difference was the 7-second pause in the delay condition. Therefore, a lack of difference in difficulty rankings indicates that the pause in the delay condition did not cause the problems to appear more difficult or to require more effort. Both of these factors may have contributed to the choice outcome - students did not identify one condition as being harder or requiring more work than the other, so it did not matter which one they chose to work again.

These results on difficulty, effort, and choice conflict with earlier studies on the additive interspersal procedure and the discrete task hypothesis. According to researchers studying the discrete task hypothesis, when completing an assignment comprised of multiple discrete tasks, each completed task is a conditioned reinforcer (e.g., Cates & Skinner, 2000; Logan & Skinner, 1998; McCurdy et al., 2001; Skinner, 2002; Skinner et al., 1999; Wildmon et al., 1998). When students are given a choice between two assignments, they are more likely to choose the assignment with the highest rate of reinforcement (e.g., Mace et al., 1990; Neef et al., 1993; Neef et al, 1992). Therefore, when given an option for their third assignment, participants in the current study theoretically should have preferred or chosen a new no-delay condition because it was associated with a thicker schedule of reinforcement. The results of this study found no support for this hypothesis as no significant differences were found between conditions when students were asked which assignment they would prefer to do again.

Other researchers suggest that students with ADHD may perform better, or at least prefer, assignments with faster pacing. Children with ADHD are more likely to attend to a stimulus with immediate rewards and reduced delays (Dalen et al., 2004; Sonuga-Barke et al., 1992). Bitsakou et al. (2006) conducted a study to measure frustration with delays during a simple computer task involving simple math problems. They found that while all students were frustrated with the delays, those students who reported a diagnosis of ADHD showed significantly more frustration with the delays than students without that diagnosis. However, the current results failed to support these researchers as there were no differences in accuracy, difficulty and effort rankings or in student choice when comparing students with low and high attention scores.

Although the current results fail to support many theories based on previous research, most of the previous researchers manipulated pace by applying procedures designed to increase, rather than decrease pace. While the implications regarding pacing from these previous studies should be able to be applied to any situation in which pacing is altered, similar findings were not replicated in the current study. Consequently, the methodology used in this study (decreasing pace) may have a significant impact on the theoretical results of these previous studies.

Applied Implications

Contrary to some previous studies, this study suggests that decreasing students' pace does not necessarily hurt their performance. According to Rowe (1974), longer wait times may be bad for students. For example, a teacher may ask a question in class and wait long enough for everyone to think of an answer to that question. While some students would formulate an answer quickly, other students would need longer to process the question and think of an answer. Those students who quickly had an answer would be more likely to become off-task and disrupt the class as well as their own focus on the academic task. The current study does not support this hypothesis because the imposed delay on the students did not hinder their accuracy levels. Therefore, teachers should not worry that waiting after posing a question during instructional time will create adverse effects for some students because delays caused by external forces do not hinder students' performance. In sum, pacing has no effect on accuracy. While this study found that increasing rates of responding does not necessarily increase performance, these results suggest that decreasing pace does not hurt performance.

Previous researchers have suggested that increasing students' pace would enhance their performance (e.g., Evans-Hampton et al., 2002; Rhymer et al., 2002; Van Houten &

Thompson, 1976; Robinson & Skinner, 2002). They proposed a causal model: a procedure (e.g., explicit timing) causes higher rates of responding, and in turn, those higher rates cause an increase in accuracy. For example, a teacher may use explicit timing as a tool to increase accuracy levels in students doing math seatwork. A causal model suggests that explicit timing is a procedure that causes students to answer the problems more quickly, and they get a higher percentage of problems correct because they are working at a faster pace. This study fails to support that pace is a causal variable in accuracy and highlights some fundamental errors in pacing research. Students did work faster in the no-delay condition than in the delay condition, but there was no difference in accuracy levels between the two conditions. Therefore, anything that increases rate will not necessarily cause an increase in accuracy. Researchers should carefully design well-controlled studies so they can look for other causal mechanisms that explain why certain procedures seem to increase accuracy.

The current study suggests that pacing has no effect on accuracy. While increasing pacing or rate of responding does not necessarily increase performance, it also does not hurt students' performance. With this finding and more controlled studies, researchers may be able to develop better and more effective interventions.

While some researchers suggest that preference is higher in faster-paced conditions due to the quicker rate of reinforcement (e.g., Billington et al., 2004; Meadows & Skinner, 2005; Wildmon et al., 2004), this study fails to support that hypothesis. While students were working at a faster pace in the no-delay condition than in the delay condition, they neither chose one condition significantly more than the other nor reported a difference in effort and choice rankings. These findings provide some insight to a question posed by Skinner (2002): previous studies that result in an identified student preference for tasks that involve a faster rate of responding also found higher accuracy levels with the tasks that had faster response rates. Therefore, it is difficult to determine whether the preference was caused by the more rapid responding or the more accurate responding. The current study resulted in no difference in accuracy between the faster (no-delay) and slower (delay) paced conditions and also in no difference in effort, difficulty, or choice between those conditions. This suggests that student preference may be influenced by more accurate responding rather than more rapid responding.

According to research, students with attention problems will especially have difficulty with slow pacing. For example, Songuga-Barke (2002) posited that individuals with attention problems prefer immediacy and have trouble with delays. Also, Bitsakou et al. (2006) found that subjects with greater attention problems became more frustrated by delays. This study attempted to measure the interaction of attention levels and delay intolerance by measuring accuracy and preference levels for each condition. There was no evidence that students with greater attention difficulties were more frustrated or negatively impacted by longer delays between problems. However, before drawing any strong conclusions regarding these results, some limitations must be discussed as this sample had a small number of students with what was labeled high attention problems on the ADHD-SC4. Because of this lack of students with high attention problems, it is difficult to analyze related results and draw any valid and reliable conclusions. There was evidence, however, that the ADHD-SC4 did indeed measure attention because the attention scores correlated with accuracy.

Strengths, Limitations, and Future Research

The current study has significant theoretical implications relative to previous studies. While other studies indicate that pacing does have an impact on students' accuracy levels and preference for the assignment, they were unable to control other possible confounding variables. Therefore, implications that could be derived from the results of those studies were limited. The current study was able to directly control both number of trials and the exact length of delay between trials. The lack of significant findings indicates that perhaps the procedures other researchers used to alter pacing or rates of responding also caused changes in accuracy.

While the ADHD-SC4 scores significantly predicted accuracy levels, the small sample size of students with high attention problems, as evidenced by their scores on the ADHD-SC4, is a major limitation of this study. However, the ADHD-SC4 is a scale that is used to measure ADHD in clinical populations. Therefore, it should not be expected that a sample from a general population (i.e., an elementary school) would have a large percentage of students with clinically severe attention problems. Future researchers may replicate this study using a larger sample size in order to include more students with greater attention difficulties.

In addition to the lack of students exhibiting high attention problems, the restricted use of grade levels, age, and locality in the sample poses threats to external validity. Only fourth- and fifth-grade students in two schools were chosen to be a part of this study, and both of those schools were located in the same town in a southeastern state. Also, the students were only examined while working multiplication problems. Therefore, the results of this study may not be generalizable to all students across the nation or across all grades and tasks due to the convenience sample.

It is possible that the nature of the activity itself (e.g., fun and enjoyable versus not fun and boring) could have impacted the results of this study. The researcher attempted to use a task that would seem boring and monotonous to students. However, this is difficult to address because there may be some variability among students. While some students may enjoy solving long math problems, other students may not like the activity at all and find it boring. The student's preexisting skill level might also influence results. A student who has trouble with math may have disliked the activity more than a student who finds math easy.

While it was previously thought that pacing was related to accuracy levels and student preference, this study suggests otherwise. Results indicate that pace by itself has no effect at all on student accuracy, nor does it influence students' choice or perceived levels of effort and difficulty. Past interventions that were thought to increase students' accuracy levels and student acceptability due to faster pacing should be closely examined to determine other factors that could explain these increases. Future researchers also should investigate the effects of different delay lengths (e.g., 20 seconds instead of 7 seconds). With more tightly controlled research studies, the results of this study can be further investigated in order to help develop better interventions.

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Appendices

Appendix A

Parental Consent Form

Dear Parent or Guardian,

My name is Emily Fuller and I am a graduate student in the school psychology program at the University of Tennessee. I am conducting research on the effects of pacing on mathematics accuracy and preference. I am particularly interested in how slow pacing may affect students with attention difficulties as opposed to students without attention difficulties. I am requesting permission for your child to participate in this study. I am hoping this study will allow us to develop better computer learning programs. I will be supervised by Dr. Christopher H. Skinner, a professor at the University of Tennessee and coordinator of the school psychology program.

If you agree to allow your child to participate, your child's classroom teacher will complete a brief 9-item rating scale regarding your child's classroom attention levels. Your child will then work on a series of multiplication problems on a computer program. After completing these problems, your child will be asked to complete a brief questionnaire regarding preference for the computer program. This session will be conducted at his/her school at a time this is convenient for both teachers and students. It will take no longer than 30 minutes. Your child's name will not be linked with the information gathered.

This study will have no effect on your child's grade. Your child is not required to participate and may choose to stop at any time without penalty.

If you agree to allow your child to participate in this research, please sign and date below and return this form to your child's teacher as soon as possible. If you have any questions or concerns about this consent form or this study, please feel free to contact me at (423)312-9872, or our faculty advisor, Dr. Christopher Skinner, at (865)974-8403. Thank you for you and your child's time and consideration.

Sincerely,

Emily Fuller
University of Tennessee
Educational Psychology and Counseling
Knoxville, TN 37996
(423)312-9872

I have read and understood the above information, and I give permission for my child to participate in this study.

Signature of parent/legal guardian: ____

Date: ____________

Child’s name (please print): ____

Appendix B

Student Assent Form

Dear Student,

My name is Emily Fuller and I am a student at the University of Tennessee. I am conducting research on math and would greatly appreciate your help. If you agree to participate, you will be asked to complete multiplication problems on a computer program for no longer than 30 minutes. You will also be asked to complete a brief questionnaire about the computer program when you finish. Your name will not be reported or linked with your performance.

Whether you agree to do this or not, your grade will not be affected. This study is completely voluntary, so you are not required to participate, and you may choose to quit at any time without penalty. You simply need to tell either me or your teacher that you no longer wish to participate. If you choose not to participate, you will stay in your classroom and complete work assigned by your teacher.

If you would like to participate, please sign and date in the space below.

Thank you,

Emily Fuller
(423) 312-9872

I have read and understand the information above. I agree to participate in this research.

Signature of student: ____

Date: ____________

Student's name (please print): ____

Appendix C

ADHD-SC4 Rating Scale

CHILD'S NAME:	DATE:
IS CHILD TAKING MEDICATION FOR ADHD?: YES NO	TEACHER:
IF YES, WHAT?____	

DIRECTIONS: BESIDE EACH ITEM BELOW, INDICATE THE DEGREE OF THE PROBLEM WITH A CHECKMARK (✓). PLEASE RESPOND TO ALL ITEMS. EVALUATE THE CHILD'S NORMAL CLASSROOM BEHAVIOR.

	NEVER	SOME-TIMES	OFTEN	VERY OFTEN
1. DOESN'T PAY ATTENTION TO DETAILS; MAKES CARELESS MISTAKES				
2. DIFFICULTY PAYING ATTENTION				
3. DOES NOT SEEM TO LISTEN				
4. DIFFICULTY FOLLOWING INSTRUCTIONS; DOES NOT FINISH THINGS				
5. DIFFICULTY GETTING ORGANIZED				
6. AVOIDS DOING THINGS THAT REQUIRE A LOT OF MENTAL EFFORT				
7. LOSES THINGS				
8. EASILY DISTRACTED				
9. FORGETFUL				

Appendix D

Procedural Integrity Checklist

_______ Researcher will call roll from groups made from parental consent forms and assign students to computers

_______ Pass out student assent forms and ask students to follow along while reading aloud

_______ Ask for questions before students assign assent forms

_______ Collect assent forms and have any student who has not signed an assent form escorted back to his/her classroom

_______ Read the following directions: "Please listen carefully to my directions before touching your computer. It is very important that there is no talking while you are here. If you have a question at any time, quietly raise your hand and someone will come around to help you. The only thing we cannot help you with is the answers to the math problems you are about to do.

Today you will be answering some multiplication problems on a laptop computer. Some of you may have used laptop computers before, but some of you have not. Instead of using a mouse to move around, these laptops have a fingerpad. You can move your finger around on the fingerpad to move the cursor on the screen. To click on something on the screen, move the cursor to it and click on the left button below the fingerpad.

When I say begin, you will click the start button on your computer screen. You will see problems come up on the screen one at a time. Please try to answer each problem as best you can. You can use the numbers at the top of your keyboard to type in your answers. If you mess up, you can use the backspace button to change your answer. After you have typed in your answer, press the enter button on your keyboard and a new problem will come up.

After you complete the first set of problems, a screen will come up with some questions for you to answer. Answer these questions and click enter, and a new set of problems will come up. After you finish those, another screen with some questions will come up. Complete those, and you will be given the last set of problems. It is okay if you do not finish the last set, but please keep working until I tell you to stop.

Remember, there is no talking and you should keep your eyes on your own screen. Your neighbor may not be working on the same problems as you, so this is your work only. If for some reason we see someone who is having trouble following these rules, that person will be asked to return to the classroom to do work assigned by the teacher. Are there any questions? If you have a question after we start working, quietly raise your hand and wait for us to come to you. You may begin."

_______ Researcher will monitor students and answer questions as needed

_______ After 30 minutes or all students are on the third set of problems (whichever is first), tell students to stop working

_______ Debrief students by pointing out that the pause between the problems in one set and not the other was the difference between the two sets and that the study was looking at whether or not they answered more problems correctly in the set without the pause, especially if they had trouble paying attention

_______ Answer any remaining questions and escort students back to their room

Vita

Emily Jane Fuller was born in Knoxville, TN on February 17, 1983. She was raised in Morristown, TN and attended West Elementary School and West View Middle School. She graduated from Morristown-Hamblen High School West in 2001. From there, she attended the University of Tennessee, Knoxville and received a Bachelor of Science degree in Psychology in 2005. Emily is currently a doctoral student in the School Psychology program at the University of Tennessee.